European Commission

Guidance on the frequency of chemical monitoring in surface waters

Common Implementation Strategy (CIS)
for the Water Framework Directive

Guidance Document No. 40

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Directorate-General for Environment
Directorate C — Zero Pollution, Water Resilience and Green Urban Transition
Unit C.1 — Sustainable Freshwater Management

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This technical document has been developed through a collaborative framework (the Common Implementation Strategy) involving the Member States, European Free Trade Association countries, stakeholder organisations, the European Environment Agency and the European Commission. The document reflects the informal consensus position on best practice acknowledged by the EU Water Directors at their meeting on 29 May 2025 in Warsaw. However, the document does not necessarily represent the position of any of the partners. To the extent that the European Commission's services provided input to this technical document, such input does not necessarily reflect the views of the European Commission.

This technical document is intended to facilitate the implementation of Directive 2000/60/EC (the Water Framework Directive, WFD) and Directive 2008/105/EC (the Environmental Quality Standards Directive, EQSD) and is not legally binding. Any authoritative reading of the law should only be derived from those two Directives themselves and other applicable legal texts or principles. Only the Court of Justice of the European Union is competent to authoritatively interpret Union legislation.

Furthermore, the legal requirements referred to in this guidance are based on the current versions of the WFD and EQSD. Please note that these requirements may change as a result of revisions to the Directives.

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Foreword

This document is a deliverable of the 2022-24 Work Programme under the Common Implementation Strategy (CIS) for the Water Framework Directive. It was drafted by a group of experts from the CIS Working Group Chemicals.

It identifies the main provisions on monitoring frequency in the Water Framework Directive and the Environmental Quality Standards Directive that are relevant to the monitoring of chemical pollutants in surface waters and considers how monitoring frequency can be optimised – to efficiently achieve reliable results - in the context of those provsions.

1. Aim and scope of the guidance

The purpose of this guidance document, which supplements Technical Guidance Documents (TGD) No. 7 and 19, is to provide experts and stakeholders with guidance on implementing the legal provisions in the Water Framework Directive (WFD, Directive 2000/60/EC) and the Environmental Quality Standards Directive (EQSD, Directive 2008/105/EC) as reqards the frequency of chemical monitoring, and presenting options for implementing them.

The guidance aims to support the interpretation of the legal provisions and promote a shared understanding of their flexible implementation. Practical examples aim to assist Member States in tailoring their monitoring efforts to available resources and specific conditions. The guidance aims to support the optimisation of monitoring programmes, including by considering where capacity for sample collection and chemical analysis can be reduced. This could free up capacity to monitor emerging pollutants or substances with highly fluctuating concentrations, or the use innovative methods such as non-target screening and modelling.

Regular reviews and, if necessary, adjustment of monitoring frequencies, at least once per River Basin Management Plan (RBMP) or in any situation pointing to a need for review or adjustment, can improve status assessment and risk management, leading to more accurate and reliable assessments and more effective implementation of targeted measures.

Structure and content of the guidance

Chapter 2	summarises the **legal provisions** relating to **monitoring frequencies** under the WFD and EQSD in the context of surveillance, operational and investigative monitoring, as well as trend monitoring and watch-list monitoring.
Chapter 3	outlines the **factors to be considered in the use of technical knowledge and expert judgement for determining the monitoring frequency** of pollutants in surface waters.
Chapter 4	provides **examples where less frequent sampling could be justified**. It outlines the reasons and information used in these expert judgements which need to be documented in the RBMP.
Chapter 5	provides **examples for monitoring substances with highly fluctuating concentrations**, where additional sampling should be considered.
Chapter 6	outlines **approaches for averaging measurements** in accordance with the monitoring objective, enabling comparison with the AA-EQS.
Chapter 7	explores the **integration of various sampling approaches into monitoring** strategies for assessing average concentrations, seasonal peaks, and long-term trends.

Using the guidance

This guidance covers Priority Substances (PS) and River Basin Specific Pollutants (RBSP). The recommendations are also applicable to other chemicals, including those on the watch list. When implementing the legal provisions on monitoring frequency summarised in chapter 2, and applying relevant recommendations from chapters 3 to 5, it is important to select an appropriate sampling method that is fit for purpose as described in chapter 7. The approaches should be adapted to specific circumstances reflecting the evolving understanding of pressures and vulnerabilities of water bodies gained from one RBMP to the next. Therefore, monitoring strategies should be be reviewed and adapted as needed within each RBMP cycle, ensuring alignment with the monitoring objectives and the required level of confidence and precision.

2. Legal provisions under the WFD and EQSD

The WFD Annex V, along with specific obligations in the EQSD, specifies monitoring frequencies, including by way of specifying monitoring intervals, for PS and RBSPs, including to assess surface water chemical (PS) and ecological (currently still RBSP as well as other quality elements) status. This chapter provides a summary of the relevant legal provisions for monitoring frequency, with a focus on their practical implications as outlined in TGDs No.s 7 and 19. The applicable provisions are presented both in textual form and as a tabular overview to facilitate understanding of the regulatory framework and to support the practical application of frequency-related obligations.

In accordance with WFD Annex V, the assessment of impacts and the analysis of pressures, as required under Article 5, serve as a basis for selecting substances to be monitored. Accordingly, only those priority substances discharged or deposited through air into the river basin or sub-basins need be monitored. Substances not present in the catchment do not need to be monitored. The selection should be based on a combination of information, including use patterns, releases from diffuse and point sources and existing data on ecological impacts. RBSP must be monitored if they are discharged in significant quantities into the river basin or sub-basin. This is particularly the case where such discharges lead to EQS exceedances or otherwise hinder the achievement of WFD objectives (CIS Guidance Document No. 7).

For surveillance monitoring, each site must be monitored for a period of one year in every RBMP cycle (6 years). However, if the status of a water body is found to be ‘good’ for a particular PS or RBSP – meaning that its EQS is met - the monitoring frequency for that substance can be reduced to once every 18 years as long as the pressures remain the same and no trend monitoring is required according to the EQSD. Within each one-year monitoring period, monthly measurements of PS and quarterly measurements of RBSP are required. It is not necessary to monitor all quality elements in the same year; phased monitoring over the RBMP period is acceptable as long as each substance is monitored for at least one year during that period.

Member States have the flexibility to adjust the surveillance and operational monitoring frequencies based on the specific conditions and variability in their own waters. If technically justified and supported by expert judgement, less frequent monitoring is acceptable. One important requirement of WFD Annex V 1.3.4 is, that “frequencies shall be chosen so as to achieve an acceptable level of confidence and precision” in the results of monitoring, and in particular in assessing the status. This means that the quality of analytical measurements as well as the amount of monitoring undertaken in terms of frequency and numbers of monitoring sites should be sufficient to obtain a reliable and robust assessment of the chemical (and ecological) status and any deterioration of status. In detail, the quality of the analytical measurements should be in line with the requirements of the Directive 2009/90/EC. The spatial and temporal coverage must be adequate to account for natural and anthropogenic variability. The higher the risk of misclassification of chemical (and ecological) status, the more monitoring may be required to accurately assess the status of a water body. This could be particularly important if the concentrations are close to the respective EQS. For further information, please see TGD No. 7.

“Estimates of the level of confidence and precision of the results provided by the monitoring programmes shall be given in the plan” (WFD Annex V 1.3). In addition, the applied frequencies for monitoring in sediment or biota and their justifications if lower than required must be included in the RBMP (EQSD Article 3 (5)). Guidance on how applied frequencies should be reported for PS is given in TGD No. 35. The WFD reporting guidance differentiates between low, medium, and high confidence levels. A high confidence level is justified when sufficient and robust data are available for all PS discharged in the river basin district (RBD), ensuring a reliable assessment of the chemical status. If monitoring data are available but lack robustness for some or all PS discharged in the RBD, the confidence level is classified as medium, reflecting some degree of uncertainty in the assessment. When no monitoring data are used for the assessment, the confidence level is low.

More frequent monitoring is always possible and especially required by WFD Annex V 1.3.4 to account for variability arising from natural and anthropogenic conditions. Monitoring times should minimise the impacts of seasonal variation so as to accurately reflect changes due to anthropogenic pressures. More frequent monitoring during various seasons within the same year may be necessary to achieve this goal. The impact of seasonal variation in water flow/level is of growing concern in the context of climate change.

According to EQSD Recital (23) and EQSD Article 3(6), monitoring strategies should be tailored to the spatial and temporal variations in substance concentrations. For substances that are widespread and have long recovery times, such as ubiquitous PBTs, Member States may reduce the number of monitoring sites and/or the frequency of monitoring to the minimum necessary for reliable long-term trend analysis, provided that a statistically sound monitoring baseline is established.

Although the watch list mechanism is not about compliance with existing standards, the choice of monitoring frequency is also an issue, as the monitoring data collected should be of sufficient quality for subsequent risk assessment processes. Therefore, requirements in relation to the frequency of the watch list monitoring are also covered in the summary provided in Table 1.

Table 1 summarises all provisions on monitoring frequency for chemical pollutants (PS and RBSPs) in the WFD and EQSD, citing the actual legal in the footnotes. Options where less frequent sampling frequencies are allowed based on technical knowledge and expert judgement are highlighted. More frequent monitoring is always possible, and for surveillance and operational monitoring purposes it is required where necessary to account for changes due to anthropogenic pressures (WFD Annex V 1.3.4).

Table 1: Summary of WFD and EQSD provisions on monitoring frequencies, highlighting (orange fill) where the legislation allows for adjusted monitoring frequencies (less frequent sampling) based on technical knowledge and expert judgement. More frequent monitoring is always possible and in particular required by WFD Annex V 1.3.4 where necessary to account for variability due to changes in anthropogenic pressures. *Text in italic font refers to substances with EQS in biota.*

WFD Annex V, EQSD Article 3 + 8a		**Frequency**	**Interval**	**Timing**
Surveillance monitoring	**EQS in water**	monthly for PS, quarterly for RBSP[1]	for a period of one year during each RBMP cycle – i.e., every 6 years if good status + no changes in emissions – once every 18 years[8]	When selecting monitoring frequencies and times, consider the variability in parameters due to natural and anthropogenic conditions. The timing of monitoring should be chosen to minimize the impact of seasonal variation on the results, ensuring they reflect changes due to anthropogenic pressures. If needed, consider conducting additional monitoring during different seasons within the same year to achieve this objective.[5]
	EQS for sediment and/or *biota* PS numbered *5, 15, 16, 17, 21, 28, 34, 35, 37, 43, 44*	at least once every year[2]		
Operational monitoring	**EQS in water**	monthly for PS, quarterly for RBSP[4]	throughout the RBMP cycle[6]	
	EQS for sediment and/or *biota*	at least once every year[2]		
	for ubiquitous PBTs (PS numbered *5, 21, 28*, 30, *35, 37, 43 and 44*)	monthly in water, once per year in biota[7]	every three years[7]	
Long-term trend monitoring	PS numbered 2, *5*, 6, 7, 12, *15, 16, 17,* 18, 20, *21*, 26, *28*, 30, *34, 35*, 36, *37, 43, 44*	once per year	every three years[3]	
Investigative monitoring	should be designed to the specific case being investigated, e.g. to identify the causes of exceedances or to assess accidental pollution			
Watch List monitoring	maximum acceptable method quantification limit[11]	once per year (preferably twice per year to take account of their fluctuating usage)[9]	over a period of two years, maximally four years[10]	When selecting monitoring frequency and timing for each substance, consider its use patterns and possible occurrence.[9]

[1]**WFD Annex V 1.3.4**: For the surveillance monitoring period, the frequencies for monitoring parameters indicative of physico-chemical quality elements […] should be applied unless greater intervals would be justified on the basis of technical knowledge and expert judgement.

[2]**EQSD, Article 3 (4):** For substances for which an EQS for sediment and/or biota is applied, Member States shall monitor the substance in the relevant matrix at least once every year, unless technical knowledge and expert judgment justify another interval.

EQSD, Article 3 (3a): Where a potential risk to, or via, the aquatic environment from acute exposure has been identified as a result of measured or estimated environmental concentrations or emissions and where a biota or sediment EQS is being applied, Member States shall ensure that monitoring in surface water is also carried out and shall apply the MAC-EQS laid down in Part A of Annex I to this Directive where such EQS have been established.

EQSD, Article 3 (5): Member States shall include the following information in the updated river basin management plans produced in accordance with Article 13(7) of Directive 2000/60/EC: […] (c) justification for the frequency of monitoring applied in accordance with paragraph 4, if monitoring intervals are longer than one year.

[3]**EQSD, Article 3 (6):** Member States shall determine the frequency of monitoring in sediment and/or biota so as to provide sufficient data for a reliable long-term trend analysis. As a guideline, monitoring should take place every three years, unless technical knowledge and expert judgment justify another interval. (additional note: This requirement is in accordance with the POPs regulation Art 13(1), 13 (2) and 10.)

[4]**WFD Annex V 1.3.4:** For operational monitoring, the frequency of monitoring required for any parameter shall be determined by Member States so as to provide sufficient data for a reliable assessment of the status of the relevant quality element. As a guideline, monitoring should take place at intervals not exceeding those shown in the table below unless greater intervals would be justified on the basis of technical knowledge and expert judgment.

[5]**WFD Annex V 1.3.4**: Frequencies shall be chosen so as to achieve an acceptable level of confidence and precision. Estimates of the confidence and precision attained by the monitoring system used shall be stated in the river basin management plan. Monitoring frequencies shall be selected which take account of the variability in parameters resulting from both natural and anthropogenic conditions. The times at which monitoring is undertaken shall be selected so as to minimise the impact of seasonal variation on the results, and thus ensure that the results reflect changes in the water body as a result of changes due to anthropogenic pressure. Additional monitoring during different seasons of the same year shall be carried out, where necessary, to achieve this objective.

[6] **WFD Annex V 1.3.2:** The programme may be amended during the period of the river basin management plan in the light of information obtained as part of the requirements of Annex II or as part of this Annex, in particular to allow a reduction in frequency where an impact is found not to be significant or the relevant pressure is removed.

[7]**EQSD, Article 8a (2):** Member States may monitor the substances numbered 5, 21, 28, 30, 35, 37, 43 and 44 (substances behaving like ubiquitous PBTs) in Part A of Annex I less intensively than is required for priority substances in accordance with Article 3(4) of this Directive and Annex V to Directive 2000/60/EC, provided that the monitoring is representative and a statistically robust baseline is available regarding the presence of those substances in the aquatic environment. As a guideline, in accordance with the second subparagraph of Article 3(6) of this Directive, monitoring should take place every three years, unless technical knowledge and expert judgement justify another interval.

[8]**WFD Annex V 1.3.1:** Surveillance monitoring shall be carried out for each monitoring site for a period of one year during the period covered by a river basin management plan for:

– priority list pollutants which are discharged into the river basin or sub-basin, and
– other pollutants discharged in significant quantities in the river basin or sub-basin,

unless the previous surveillance monitoring exercise showed that the body concerned reached good status and there is no evidence from the review of impact of human activity in Annex II that the impacts on the body have changed. In these cases, surveillance monitoring shall be carried out once every three river basin management plans.

[9]**EQSD Article 8b:** In selecting the representative monitoring stations, the monitoring frequency and timing for each substance, Member States shall take into account the use patterns and possible occurrence of the substance. The frequency of monitoring shall be no less than once per year.

[10]**EQSD Article 8b (2):** The duration of a continuous watch list monitoring period for any individual substance shall not exceed four years.

[11]**Comission Implementing Decision (EU) 2022/1307 Recital 11**: … the method detection limit should be, for each substance, including each individual substance in a group, at least as low as the substance-specific predicted no-effect concentration in the relevant matrix. For the newly-added substances, the method quantification limit should be, for each substance, including each individual substance in a group, at least as low as the substance- specific predicted no-effect concentration in the relevant matrix.

In addition, there are requirements for the analytical methods used and the compliance assessment. According to the Directive 2009/90/EC, the limit of quantification (LOQ) should be equal to or below a value of 30 % of the relevant EQS. If such methods are unavailable, monitoring should rely on the best available techniques not entailing excessive costs. Monitoring results for single substances below the LOQ should be set to half of the LOQ for the calculation of the annual average (AA). Whereas monitoring results below the LOQ for substances within a group of substances shall be set to zero for the calculation of the arithmetic mean. If, according to Article 3 (3b) of the EQSD, the calculated mean value of a measurement using the best available technique is below the LOQ, and the LOQ is above the EQS, the result for that substance shall not be considered when assessing compliance with the EQS.

An example of a decision-making scheme based on the legislative provisions is presented in Annex I. This scheme has been developed to assist water managers in determining whether, where, and when a substance should be monitored, aiding in the selection of relevant substances, locations, and monitoring frequency for the monitoring of both PS and RBSP in water and biota.

Factors that influence sampling frequency as well as options for adjusting this frequency in line with the legislative provisions are presented in the following chapters. The examples provided are for guidance and the approaches taken in them should be adapted to the specific circumstances.

3. Key factors to consider when using technical knowledge and expert judgment to determine monitoring frequencies

When determining or adjusting monitoring frequencies using technical knowledge and expert judgment, several factors must be taken into consideration to ensure reliable status and trend assessment. These factors include:

Legislative requirements	**Monitoring objective**	**Define goals for the surveillance, operational or investigative monitoring (see TGD No. 7)**, e.g., – assessing compliance with AA-EQS, MAC-EQS and non-deterioration principle – tracking trends over time – identifying pollution sources – defining or evaluating measures **Identify accuracy and precision needs**
	Monitoring frequency or interval	**Check mandatory requirements** in WFD + EQSD as well as their national implementation with respect to frequency or interval and timing (see chapter 2)
	Timing	Consider factors determining the **seasonality** in the concentration of substances (e.g. water discharge and related dilution, use/application period, snowmelt runoff of atmospheric pollutants, rainfall driven runoff of pesticides, mobilisation of persistent compounds from sediment and floodplains during peak water discharges, degradation of compounds)

Available Data and Information	**Existing monitoring data**	**Analyse existing** incl. historical and background **data**
		– verify their quality in line with Directive 2009/90/EC requirements, e.g. LOQ ≤ 30% EQS
		– check representativity (spatial coverage)
		– assess achievement of WFD objectives laid down in Article 4 (EQS compliance, non-deterioration, no significant increase in sediment/biota concentrations)
		    o determine extent of exceedance/distance to target and temporal trend
		– assess the level of confidence and precision achieved in the assessment of existing monitoring data as
		    o high (robust data)
		    o medium (incomplete data)
		    o low (no data)

	Pollutant characteristics	**Consider pollutants´ behaviour in water bodies**, including its emission sources, transport mechanisms, and seasonal patterns influenced by hydrological conditions and weather patterns, take physico-chemical properties into account **Determine variability in time and space:** analyse how pollutant concentrations vary over time, assess differences in pollutant levels at different locations across a water body, such as upstream vs. downstream or near pollution sources vs. distant areas

	Environmental conditions	**Consider seasonal variations:** understand how seasons and climate affect water quality **Review hydrological factors:** assess flow regime, temperature, and rainfall patterns **Consider geological conditions** such as soil permeability, rock type, sediment dynamics, and groundwater interaction that significantly influence the fate of chemicals (transport, degradation, accumulation) **Examples:** identify areas with high runoff potential (e.g., steep slopes, impermeable soils) with significant pesticide transport to surface waters; consider groundwater recharge zones at risk from pesticide leaching
	Biological quality elements of ecological status	Take into account results on biological quality elements indicating impact from chemical pollution, e.g., a decrease in species diversity or the dominance of pollution-tolerant species may indicate chemical stress
	Water use and chemical pressures and impacts	Consider pressure and impact analysis, including inventories of emissions, discharges, and losses e.g., water abstraction, flow regulation, pollution sources, use pattern and possible occurrence in water bodies **Examples of factors for identifying suitable monitoring stations and sampling periods:** compile nationally approved plant protection product (PPP) uses by crop type (e.g. https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database_en), review production and use data e.g. from REACH or point source information reported into the Industrial Emissions Portal

Resources and capacities	**Resource availability**	Evaluate the availability of financial, technical, and human resources needed to conduct monitoring, including sampling, laboratory analysis, data management, and reporting
	Technical capabilities	Review availability and reliability of monitoring equipment and methods (e.g. LOQs) Evaluate logistical constraints for accessing sites Consider the implications of logistical challenges and potential errors when implementing a complex monitoring programme

By considering these factors, water managers can develop monitoring plans that are scientifically sound, cost-effective, and tailored to the specific conditions and objectives of their water management programmes. Regular reviews of monitoring data can inform adjustments to monitoring frequencies based on new information and evolving conditions. Monitoring frequencies should be reviewed at least once per RBMP cycle, especially if uncertainties hamper reliable status assessment. Additionally, frequencies may also be adjusted in response to significant environmental changes. Any modifications should ensure that monitoring provides a high level of confidence and precision in the water status assessment to prevent misclassification.

4. Situations where less frequent monitoring could be justified

This chapter outlines examples of situations where Member States could, based on technical knowledge and expert judgement, justify less frequent monitoring than otherwise required by the WFD and EQSD, while still ensuring a high level of confidence and precision in status and trend assessment. The described scenarios aim to support informed decision-making and are intended to be adapted on a case-by-case basis taking into account specific water body characteristics and monitoring objectives.

For example, if the available monitoring data from surveillance monitoring confirm that concentrations of PS that are no longer in use (e.g., atrazine, chlorpyrifos) do not exceed the EQS at most monitoring sites in the national river basins over one RBMP period, Member States may consider focusing further operational monitoring on those sites where EQS are still exceeded. In such cases, the frequency of monitoring at these sites could also be adjusted based on the substance's behaviour and natural conditions. Substances with consistent presence (e.g., persistent substances adsorbed to organic matter) may require only quarterly monitoring, while those with fluctuating and unpredictable presence may still need monthly monitoring.

A reduced monitoring frequency for the upcoming RBMP or a further gradually reduced monitoring frequency over subsequent RBMPs could be justified for well-monitored pollutants if it is ensured that sufficient data are available for a robust status assessment. In particular, for the monitoring of ubiquitous persistent, bioaccumulative and toxic substances (uPBTs), there might be a need to optimise the monitoring frequency. These pollutants are often characterised by slow decreases in environmental concentrations, still exceeding the EQS, despite EU-wide measures. The presence of these pollutants in the water bodies may be attributed to historical contamination or legacy sources, which are gradually decreasing over time. In such situations of declining or stable pollutant levels, it could be justified to focus on trend monitoring in sediment or biota at selected monitoring sites (critical locations, e.g., near pollution sources, sensitive ecosystems) and allocate resources accordingly (excluding low-impact areas). Once sufficient monitoring data are available, preferably data from at least five years to ensure a reliable trend assessment, the monitoring frequency could be further reduced to once every three years as recommended for temporal trend monitoring in Article 3(6) EQSD. These monitoring data ensure a robust level of confidence and precision in assessing the chemical status and tracking progress in achieving the EQS. TGD No. 25 gives more guidance on sediment/biota monitoring (including the selection of matrices and trend analysis).

In water bodies where the EQS in biota is exceeded but the MAC-EQS in water is met, indicating no acute risk according to EQSD Art 3(3a), monitoring in water is not needed if monitoring is conducted in biota for comparison with the biota EQS. So monitoring in water could stop as long as the pressure and impact analysis does not show that an acute risk is possible.

In other cases, with stable ecological status and reduced human impact due to implemented measures, it could be justified to reduce the frequency of operational monitoring from monthly to quarterly without compromising the ability to detect significant changes in concentrations of priority substances or assess overall water quality trends. The reduction in monitoring frequency would allow for more efficient resource allocation and prioritisation of monitoring efforts. If data are generated quarterly every year or every second year during the RBMP period, the data collected remains reliable and sufficient for accurate water quality assessments.

In some cases, local difficulties related to accessibility could justify a reduced monitoring frequency. Certain water bodies, such as those in remote or difficult-to-reach areas, can pose significant logistical challenges for regular sampling. These challenges include rough terrain, harsh weather conditions, limited transportation options which depend also on the substance to be analysed, and safety concerns for monitoring personnel. Reducing the frequency of monitoring priority substances in those water bodies could be justified if it is ensured that sufficient data from at least four data points over the course of one year are still collected to provide reliable assessments. Alternative strategies, such as installing automated sampling equipment, could help supplement less frequent manual sampling. The stability of the sample should be carefully evaluated in these cases.

In some surface water bodies, monitoring can only be conducted less frequently because these water bodies are intermittently dry. In the case of ephemeral rivers, the recommended matrix for compliance assessment is sediment and the frequency could be once per year at the end of the wet season, before the dry period. In the case of temporary rivers which are characterised by frequent but short periods of drought, it is often difficult to predict the flow regime (no-flow periods and rewetting) and respond with appropriate monitoring. Here, the flow regime must be carefully examined to determine whether it has been influenced by human activities. For water bodies that dry up early in the year (first quarter), it could be assumed under certain circumstances that they will remain dry for the rest of the year. Consequently, only three (monthly) water measurements within the first quarter could be available for these water bodies for status assessment. Another example is frozen water bodies, where monitoring can also be temporarily hindered. However, if a water body dries up in the first quarter, it does not mean that it will remain dry the rest of the year and it also does not mean that it will dry up during the same period in the following year. Furthermore, it is possible that at times during the rest of the year that water body could contain water (for instance in the autumn or following rainfall events). Therefore, the period for taking water samples should be adjusted according to the hydroperiod and always when it is not dry. For lakes, if the lake is ice-covered in winter, water samples should be collected from the outlet (if accessible) because they are usually representative of the substance concentrations in the entire lake, or, if possible, by drilling through the ice and sampling from 1 m below the ice-cover.

Below are examples of situations where justifications were given for less frequent monitoring. In all the examples, use was made of existing information and monitoring data sets on chemical and ecological status to identify trends and establish baselines that supported reduced monitoring frequencies. In addition, pollution pressures due to human activities were documented as being stable, decreasing or posing a low risk of pollution. Not all examples are currently being implemented, but they illustrate justifications that could be included in RBMPs.

Situation	Adjusted monitoring frequency	Justification on the basis of technical knowledge and expert judgement according to WFD Annex V 1.3.4
During the 1st RBMP period, concentrations of dichloromethane and 1,2-dichloroethane were below EQS, even below LOQ in Austrian waters	No monitoring in the 2nd RBMP period, but further monitoring in the 3rd RBMP period	The monitoring interval was reduced by not performing the surveillance monitoring during the second RBMP, as the monitoring data consistently indicated compliance with the EQS. Additionally, analysis of pressures and impacts did not reveal any evidence of significant changes. Therefore, the decision to lower the monitoring interval was supported by consistent compliance with the EQS and the absence of notable changes in pressures and impacts.
uPBT Hg and PBDE levels exceeded the respective EQS in fish in Austrian waters, also at monitoring stations in remote areas without anthropogenic pressures	Surveillance monitoring in 2013, followed by trend monitoring every three years, next surveillance monitoring in 2025	The inventory of emissions based on modelling following the pathway-oriented approach according to CIS Guidance Document No. 28 showed that diffuse emissions in the form of atmospheric deposition, and emission pathways (including erosion) linked to atmospheric deposition, were the major pressures. If the regularly updated inventory of emissions does not provide any evidence of changes in pressures and impacts and the trend monitoring continues to result in exceedances of the biota-EQS, a reduction in the monitoring frequency for surveillance monitoring for ubiquitous PBTs resulting in a failure of good status is regarded as justified.
Data on chlorpyrifos generated between 2014-2023 exceeded the EQS only at a few monitoring sites in Portuguese waters	Surveillance monitoring twice per year in spring and autumn every year since 2020, additional operational monitoring at sites with EQS exceedances	The decision to reduce the surveillance monitoring frequency for chlorpyrifos was justified by several factors. Firstly, the use of chlorpyrifos has been restricted (PPP with Chlorpyrifos are not authorised anymore since April 2020), which significantly reduces the potential for new inputs into the environment. Secondly, any exceedances observed can be expected to be primarily due to diffuse historical contamination released from agricultural fields or sediments into the water bodies. This historical contamination results in a more predictable and stable concentration pattern, allowing for less frequent monitoring without compromising the accuracy of the data. Therefore, biannual monitoring is sufficient to check EQS compliance and to track any long-term trends in contamination. To account for natural variability during dry or wet years, surveillance monitoring will be conducted annually for the whole RBMP. This assessment will be reconsidered if substantial emergency use of chlorpyrifos-containing PPP is authorised or the EQS is revised.

Levels of dichloromethane < LOQ that fulfil the minimum performance criteria of Directive 2009/90/EC in German waters	Surveillance monitoring once every 3rd RBMP	The surveillance monitoring frequency can be reduced to once every 18 years, as the EQS is not exceeded and the use restricted according to REACH, such that no change in the pressures can be expected.
Levels of Hexachlorobutadiene and HBCDD in biota < EQS in all German water bodies	Surveillance monitoring once every 3rd RBMP in water, trend monitoring every three years	The surveillance monitoring can be reduced to once every 3rd RBMP, as monitoring data consistently indicates compliance with the EQS. Additionally, analysis of pressures and impacts does not reveal any evidence of significant changes. Therefore, the decision to lower the monitoring interval is supported by the consistent compliance with EQS and the absence of notable changes in pressures and impacts. For POPs which tend to accumulate in sediment/biota, long-term trend monitoring has to be performed every three years.
Levels of Pentachlorophenol, Cyclodiene pesticides, Endosulfan in water < EQS in all German water bodies	once every 3rd RBMP	
TBT with relatively stable concentrations in water exceeding the EQS in German waters	Quarterly monitoring in water	Lowering the monitoring frequency from monthly to quarterly conserves resources, including personnel, equipment, and funding, without compromising the ability to detect significant changes in pollutant concentrations or assess overall water quality trends with sufficient confidence and precision. The reduction in monitoring frequency allows for more efficient resource allocation and prioritisation of monitoring efforts.
Slow improvement in the levels of PS exceeding the EQS during the implementation of mitigation measures in Austria	Monitoring monthly over one year, once in biota before and after finalisation of measures	In water bodies at risk of failure, where operational monitoring has shown that measures need to be planned and implemented, but only slow improvement in the situation is expected. This is in line with the aim of the operational monitoring to assess status and any changes in the status of water bodies resulting from the programmes of measures. During the implementation period, continuous operational monitoring is not deemed necessary where improvement is slow, and a reduction in the monitoring frequencies seems justified. After finalisation of the measures (but at the latest in the next RBMP period), operational monitoring is repeated to assess whether these measures have been sufficient.

5. Situations where more frequent monitoring should be considered

Monthly sampling via grab samples is good for measuring the concentrations of substances that are continuously discharged into water bodies. However, for substances with highly fluctuating concentrations, such as those influenced by rainfall events, fluctuating use patterns (in particular where urban waste water discharges and spray drift are relevant), industrial batch production discharges, or seasonal tourism activities, enhanced sampling frequencies should be considered to correctly detect concentrations of those substances for a correct risk assessment. Grab sampling has been shown to underestimate concentrations of dynamically discharged substances, especially in small- to medium-sized streams (Wittmer et al. 2014, Weber et al. 2024), which can lead to misclassification. More frequent monitoring is particularly important when, on the basis of monthly measurements, there is a risk that a water body may be misclassified as not at risk of failing environmental objectives when, in reality, it is at risk. Increased monitoring may also be necessary when pollutant levels are close to the respective EQS to improve confidence in the status assessment and prevent misclassification.

TGD No. 7 and 19 provide several recommendations with respect to more frequent monitoring, which are summarised in the following paragraphs. As summarised in chapter 2, the WFD requires in Annex V 1.3.4 that the temporal variability of the measured parameters shall be considered when choosing the monitoring frequency and that they shall reflect the changes in the water body as a result of changes due to anthropogenic pressures. For uPBTs less frequent monitoring is explicitly allowed (EQSD Article 8a (2)). TGD No. 7 states that “the actual confidence and precision achieved by monitoring at any particular monitoring site will depend partly on the variability (both natural and resulting from anthropogenic activities) of the determinand being measured, and the frequency of monitoring. […] Member States are able to target their monitoring to particular times of year to consider variability due to seasonal factors. […] Seasonal sampling to reflect seasonal human pressures is also permitted.”

TGD No. 19 further specifies that, “for pesticides and other seasonally variable substances, more frequent sampling may be necessary […] to achieve acceptable levels of confidence and precision in assessing the status of water bodies” and that “flow-proportional or time-proportional samples” (e.g. of 24h to one week) “may be better” than spot samples.

With respect to the interval of sampling, TGD No. 7 specifies the following: “An objective of surveillance monitoring is to assess the long-term changes in natural conditions and long-term changes resulting from widespread anthropogenic activity. The minimum frequencies given in the Directive may not be adequate to achieve an acceptable level of confidence and precision in this assessment. It may therefore be necessary to increase the frequencies of at least some surveillance monitoring parameters and monitor more than once every sixth year at those surveillance sites designed to detect long-term changes.”

For investigative monitoring there are no specific frequency requirements in the WFD. The frequency should be determined according to the problem being investigated (TGD No. 7). Examples include identifying causes of water body failure, assessing impacts of accidents or pollution incidents, verifying the effectiveness of measures, investigating emerging contaminants or unknown pollutants, pinpointing pollution sources, assessing biological quality elements, evaluating hydromorphological changes, and responding to public or regulatory concerns. A comparatively high monitoring frequency might be needed.

In the following sections, practical examples are given that illustrate how increased monitoring frequency is implemented in various contexts. All examples clearly show that more frequent monitoring is necessary to capture the real concentrations of substances being emitted irregularly such as pesticides or substances from industrial production processes. If more frequent monitoring is not carried out, significant underestimation of those concentrations is likely, resulting in incorrect assessment against both the MAC-EQS and the AA-EQS, and potentially in failure to detect ecological risks.

5.1 Monitoring of organic micropollutants in Switzerland

Background: In Switzerland, the federal government and the cantons jointly operate the national monitoring programme for surface waters. It has the goal of recording the status and development of surface water quality on a long-term and uniform basis, and of monitoring the impact of measures to improve water quality (BAFU 2013). In 2018, the national monitoring programme was extended to include the measurement of micropollutants. Regarding micropollutants, surface water quality is assessed according to three criteria: a) compliance with the numerical requirements of the Water Protection Ordinance (these equate to the quality standards under the WFD), b) ecotoxicological risks posed to aquatic organisms and c) high concentrations and loads in general (Doppler et al. 2020).

Site selection: The 38 monitoring sites of the national surface water monitoring programme were selected such that they represent the variety of types of watercourses in Switzerland that are contaminated with micropollutants from agricultural or urban sources. The monitoring sites represent the variety of watercourses with respect to their size, and the land use in their catchment.

Different sizes: Around 75% of the watercourses in Switzerland are small streams with a discharge of less than 0.1 m^3/s. Scientific studies showed that the highest pesticide concentrations are often found in such small streams. However, urban micropollutants are usually found in medium-sized to large streams, since wastewater treatment plants don’t usually discharge into small streams in Switzerland. In large rivers, micropollutant concentrations are often diluted to a level that do not pose a risk. However, large rivers have the advantage that they integrate information from a large catchment. Consequently, to obtain a full picture of the quality of Swiss watercourses, several monitoring sites were installed for each size of watercourse: 12 sites at small streams (< 7 km^2), 16 sites at medium-sized streams (7-45 km^2), 7 sites at large streams (45 - 2000 km^2), and 3 sites at large rivers (> 2000 km^2).

Different types of land use: Additionally, the monitoring sites were selected such that they cover the whole variety of watercourses in Switzerland with respect to the fraction of agricultural and urban land use in their catchment, and to the fraction of treated wastewater in their total discharge. The fraction of agricultural land use (i.e., arable land, orchards, and vineyards) is intended to represent the potential for pesticide pollution. The fractions of urban land use and treated wastewater are intended to represent the potential for the pollution with urban micropollutants.

Sampling: The monitoring frequency was chosen to assess the risk posed by dynamically and continuously discharged substances at the same time. The frequency chosen is based on the average duration of ecotoxicological tests (further explanation in chapter 6.1). The numerical requirements to assess long-term effects on aquatic organisms (= AA-EQS) set in the Swiss Water Protection Ordinance (WPO) apply to the concentration averaged over a period of two weeks. Therefore, time-proportional two-weekly composite samples (14 days) are taken at all monitoring sites throughout the year, resulting in 26 samples per year. The chronic risk is evaluated from each two-week sample by comparing the concentration in the two-week sample to the AA-EQS. Any measured concentration that is higher than the AA-EQS is counted as an exceedance. The acute risk is evaluated at a subset of sites. At these sites, the frequency of sampling for time-proportional composite samples is increased to 3.5-days in some months, typically from April to September. The concentration of each composite sample is compared to the MAC-EQS. Any concentration higher than the MAC-EQS is counted as an exceedance.

The sampling sites are monitored for at least four years, but in most cases for much longer. Samples are collected using autosamplers and then cooled to 4°C prior to analysis in the laboratory.

Substances measured: Within the national monitoring of organic micropollutants a defined set of substances is measured using liquid- and/or gas chromatography coupled to high-resolution mass spectrometry. Approximately 80 substances are measured on a mandatory basis, while a further 45 substances are recommended, but optional. Depending on the canton, further substances are analysed at individual sites. The set of substances is defined for each four-year period, with the possibility of slight adaptation within that period.

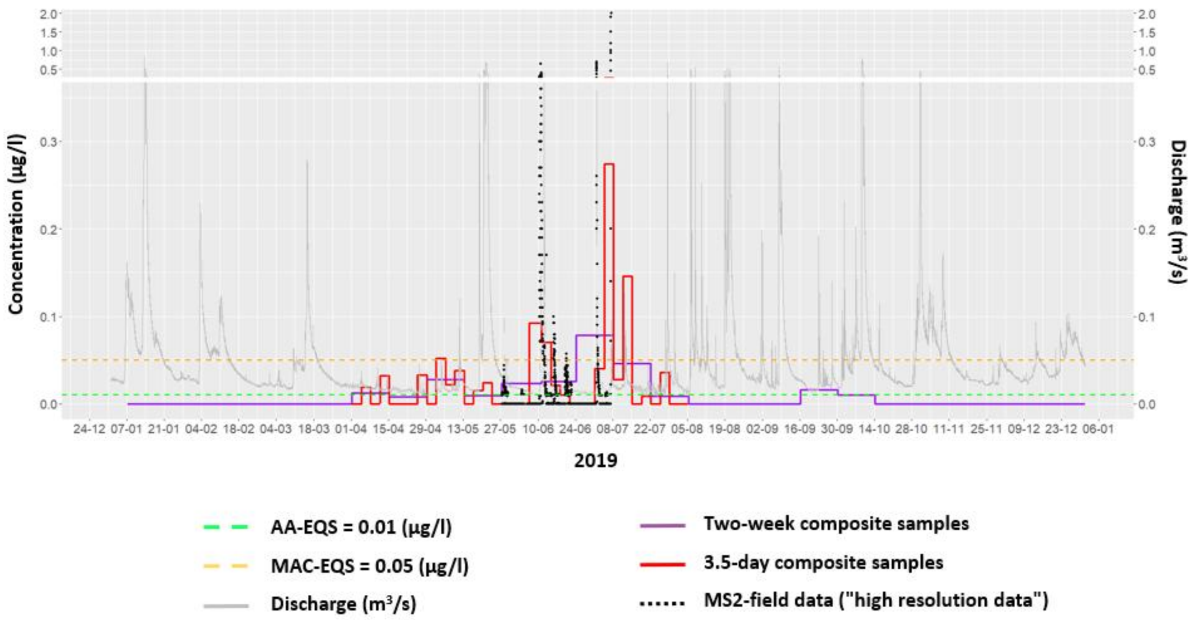

Figure 1: Concentration dynamics of the pesticide thiacloprid in a small water body in Switzerland in 2019 detected by different sampling approaches. Sampling was carried out all year round using two-week composite samples, for 4 months using 3.5-day composite samples and for 6 weeks at a high temporal resolution of 20-minute intervals.

5.2 German monitoring campaign of plant protection products (PPP) in small streams

Background: In the context of the German national action plan on sustainable use of plant protection products (NAP), monitoring of PPP residues in small water bodies was performed in a joint project by the German Environment Agency (UBA) and the Helmholtz-Centre for Environmental Research (UFZ) in the years 2018/2019 in 91 streams in German agricultural areas. This monitoring was done to assess the extent of exceedance of thresholds (EQS and regulatory acceptable concentrations (RAC)) as defined in indicator 4 of the German Plant

Protection Index (PIX) within the NAP. The RAC is usually compared to predicted peak exposures when assessing the environmental risk during authorisation. Since for most active substances in authorised PPP no EQS are available, RACs were used to assess measured concentrations. To comply with a MAC-EQS, no exceedance should occur at any time, so RAC values were also compared to single measurements (without the application of statistical methods according to the German Water Protection Ordinance 2016). Previous monitoring showed that on days with rain events the probability of positive findings was highest. The project thus focused on capturing short-term peak concentrations after rain events. For comparative reasons, grab samples were taken at fixed time intervals, independently of precipitation. Based on the results, azoxystrobin, dimethenamid, and foramsulfuron have been proposed for inclusion in the list of river basin specific pollutants in Germany. Resumption of the monitoring of small streams, on a reduced scale, is also being considered, to keep track of their pollution and further assess whether related goals of the German National Action Plan (NAP) on the sustainable use of pesticides are being fulfilled.

Site selection: The focus of this monitoring was to assess the risks posed by PPP in small water bodies in agricultural areas. Therefore, criteria for sampling sites were a catchment size of <30 km^2 with a percentage of at least 40% agricultural area in the catchment and < 5 % urban area (Wick et al. 2019, Weisner et al. 2022). The actual monitoring sites largely fulfilled these criteria, where the hydrological catchments were mostly <30 km^2 (mean = 19 km^2, 34 % <10 km^2) with an agricultural land cover ranging from 22% to 100% (mean = 75%).

Sampling: Water sampling was carried out in two different ways: (i) grab samples (n = 450) were taken in a regular, three-week cycle, comparable to the monthly sampling under the WFD. Sampling was thus carried out independently of weather and discharge conditions. (ii) In addition, the streams were sampled directly after rainfall, which presumably led to surface runoff (n = 312), using automatic sampling devices that take time-proportional composite samples ((40 subsamples over 200 minutes) when the water level rises significantly. In total, an average of 4 - 5 grab samples and 3 - 4 event-driven samples were taken per stream and year. In addition to water sampling, passive sampling (in all streams), sediment and suspended-matter sampling (10 streams in a follow-up monitoring exercise in 2021, with a focus on pyrethroids) were conducted. Further details on the sampling, and publications from the project, can be found here: Overview - Monitoring of Small Streams (ufz.de). Monitoring results were compared with the EQS in the German Water Protection Ordinance for priority substances and river basin specific pollutants and the RAC-values from PPP authorisation. Only for a fraction of the substances were EQS available. The results are reported in a Shiny app (https://www.ufz.de/kgm/index.php?en=48130).

Sampling period: Previous data have shown that during the main application period of PPP from April to June the probability of finding active ingredients which are transported into streams related to rainfall is highest. Therefore, the sampling period was chosen to include these months in this monitoring which aimed at taking account of runoff and discharge during rain events.

Substances measured: Substances were selected based on previous monitoring results (detection frequency, RAC, and MAC-EQS exceedances). Furthermore, PPP active substance sales were considered in order to select currently used active substances. In all, 86 active ingredients and 32 transformation products were analysed specifically (targeted analysis), and screening analysis for 385 substances was also conducted.

5.3 Swedish national environmental monitoring programme of pesticides in surface water

Background: In 2002, Sweden set up an environmental monitoring programme for chemical pesticides (mainly PPP) in surface waters with a focus on agricultural regions. The aim of the programme is to capture pesticide occurrences in surface water by sampling two rivers (water bodies) and four small streams in agricultural catchments. The so-called model catchments were chosen to reflect reality and represents intense (“worst-case”) current conventional agricultural management practices in these regions. Long-term, continuous (weekly or two-weekly), time-proportional, comprehensive analyses of most EU-listed priority pesticides and almost all active substances (and a number of metabolites) registered for use in Sweden are conducted. The list includes glyphosate and its metabolite AMPA, which are often omitted from monitoring programmes due to analytical difficulties. Due to low detection and quantification limits of the analytical methods used, substances such as pyrethroids and neonicotinoids, which are highly toxic, are also analysed. Thus, the dataset generated to date provides a uniquely comprehensive, long-term representation of how Swedish agricultural pesticide use affects surface water quality.

The water-quality monitoring in these agriculturally dominated catchment areas is not primarily intended for checking WFD compliance. However, from certain monitoring stations it provides representative and valuable data for status classification. This applies in particular to measurements from the two rivers. The ambitious sampling scheme provides knowledge on how the concentrations of nutrients and pesticides can vary over time in rivers and small streams. Data is used by researchers and authorities to evaluate sampling methodology and to determine which pesticides (not only PS) should be analysed also in other relevant water bodies.

Site selection: The surface water sampling is done in the agricultural catchments of two rivers (100-500 km^2; >50% agricultural land) and four small streams (8–16 km^2; 85 to 92% agricultural land). Informed decisions were made to target catchments and rivers that would be representative of the main agricultural regions in terms of soil types, agricultural practices, and major crops grown.

Sampling: Rivers are sampled 9 times per year by grab sampling, during May to November, i.e. during the growing season. Model catchments are sampled through continuous time-proportional composite sampling (subsamples every 90th minute) on a weekly basis from May to October or November. In two catchments the monitoring continues throughout the winter season (December to April) with two-weekly time-proportional composite sampling (subsamples every 180th minute). In addition, flow-proportional sampling is done in one of the four catchments to capture short-term water flow increases resulting from rain events. This sampling is done to study whether they result in elevated pesticide concentrations that could indicate acute toxic effects to the water ecosystem. The sampling in model catchments is done with an automatic sampler including a +4°C refrigerator with one glass bottle and one plastic (high-density polyethylene) bottle for storing samples for different types of analyses.

Sampling period: Continuous monitoring during the growing season, and at some sites throughout the year, has been conducted since 2002. This generates long-term data on chemical pesticides in surface waters.

Substances measured: The programme aims to analyse all pesticides approved for agricultural use in Sweden, as well as pesticides listed as PS under the EQSD, including several never authorised nationally. New substances that are introduced into the Swedish market are normally added to the list of analytes the following year, as long as they are being used in the model catchments and there is an existing analytical procedure to detect them. Banned substances remain on the list of analytes until the concentrations are consistently below the analytical detection limit. Thus, the pesticides included in the analyses are reevaluated before each monitoring season in response to pesticide sales and usage regulations, but in general, the list is expanded yearly. Overall, the list has expanded from around 80 to 150 different substances during the period 2002 to 2022.

Note: Text slightly adapted from Boye et al. 2019 and Spycher et al. 2024.

5.4 Austrian campaign: Comparison of monitoring strategies for micropollutants in surface waters

Background: The StraMoS-project investigated whether different sampling strategies lead to significantly different estimates of mean and maximum concentrations and their potential impact on the assessment of the chemical status of water bodies, as well as of annual riverine loads of trace contaminants in rivers (Weber et al. 2024). To address these research questions, a comprehensive review of the literature was conducted, and a one-year monitoring programme was implemented. Three sampling methods (grab sampling, time- and flow-proportional continuous two-week sampling) were applied in parallel at two sites located in the catchment of the River Wulka in Eastern Austria.

Site selection: Two sites within the catchment of the Wulka river (389 km^2) were selected. The monitoring site at the Wulka river has a large portion of agricultural area (52%) and is also heavily influenced by discharges from municipal wastewater treatment plants, which account for about one third of the annual mean water flow. The other monitoring site is located at the tributary of the Wulka, the Nodbach river with a catchment size of 76 km^2. It is also strongly influenced by agriculture (64%) but receives no wastewater treatment plant discharges.

Sampling: Grab samples were taken at both sampling locations at 14-day intervals, while composite samples were collected over 14 days by using two parallel automatic cooled samplers for time-proportional and flow-proportional sampling.

Sampling period: The sampling was carried out during a one-year period from 27.06.2023 until 25.06.2024.

Substances measured: Micropollutants from various substance groups were selected which are representative of different emission sources and input pathways, as well as different transport dynamics. The following groups of substances (with the number of individual parameters) were studied: 8 metals (dissolved and total), 4 pharmaceuticals from human medicine, which are mainly emitted via sewage treatment plant discharges, 34 per- and polyfluorinated alkyl substances (PFAS), as representatives of industrial chemicals with a wide range of uses, and 404 pesticides.

Comparison of sampling strategies: For the mean annual concentrations, the mean concentration of the time-proportional composite samples is considered to be the concentration that best reflects the actual conditions. This assumption is based on the fact that, with the time-proportional composite sample, sampling is repeated at regular short intervals (quasi-continuously) and the sample is composed of a large number of individual samples. This type of sampling was therefore used as a reference value or as a basis for assessing the suitability of using the results from the grab samples for calculating the annual average concentrations. The value from the mixed samples is compared with the mean concentration from 12 grab samples; 12 because this is the number used for checking compliance with the AA-EQS for surface waters according to the EU WFD and the Austrian Quality Target Regulation for Chemistry of Surface Waters. The annual maximum concentrations must be monitored according to the requirements of the Austrian Quality Target Regulation for Chemistry of Surface Waters using the 90th percentile of the monitoring results. In the course of this study, the 90th percentile of the concentrations of the flow-proportional composite samples is considered to be the concentration that comes closest to the real conditions under the sampling strategies used due to the assumption that increased concentrations occur with peak flows. However, better recording of the maximum concentrations via time-proportional composite samples can be expected if concentration peaks occur in the water independently of runoff events. Therefore, the results of flow-proportional sampling were always compared with those of time-proportional sampling.

<u>Main outcomes regarding more frequent monitoring:</u> Substances being emitted more or less continuously, such as pharmaceuticals, certain pesticides (glyphosate and diuron) and dissolved metals, can be measured well via monthly grab sampling. For substances with irregular emission patterns, such as particulate metals, some PFAS (PFNA, PFOS and 6:2 FTS) and several pesticides (MCPA, metolachlor, benalaxyl, spiroxamine), grab sampling was found to systematically underestime annual average concentrations. The pesticide lindane was detected in all composite samples but in none of the grab samples. Therefore, composite sampling is required for those substances. Depending on the sampling method and substance, the mean and maximum concentrations sometimes show significant deviations from one another, but the assessment is usually the same because exceedance of or compliance with the EQS (or the reference values of the substances considered) is usually very clear. If the concentrations of substances are close to the EQS, then underestimations with grab samples may lead to a different assessment and thus to unrecognised failures in compliance.

For the detection of the annual loads, the suitability of grab samples decreases significantly (e.g. for total metals, sum of 24 PFAS) in the studied watercourses, compared to flow-proportional sampling, recording less than half of the annual load.

The StraMoS-project has shown that for priority substances, including future priority substances such as pharmaceuticals, grab sampling and composite sampling generally lead to the same status designation, depending upon the substance. Due to the significantly higher costs of composite sampling compared to grab sampling, the introduction of composite sampling will be limited. Furthermore, composite sampling will result in a fixed monitoring network, thus reducing flexibility and contradicting the concept of variable and pressure-oriented monitoring. It may make sense to set up composite sampling in specific selected catchment areas with the aim of detecting pulse emissions, determining loads and identifying emission pathways. However, it remains unclear to what extent the results generated for a specific catchment area can be transferred to other catchments. A case-by-case evaluation is necessary of whether the expected benefits of composite sampling (compared to grab sampling) justify higher costs and efforts.

6. Assessment of measured concentrations

Depending upon the objective of the monitoring, different approaches may be used to calculate a time-weighted average (TWA) of the measured concentrations for comparison with the AA-EQS:

1) based on measurements over one year
2) based only on measurements from months when a substance is present in the respective water body or even only on those from the most critical consecutive shorter averaging periods (e.g. two weeks).

Each method has its own purpose and implications. However, the two approaches can complement each other. The **first approach** provides a broader perspective on the overall presence of substances throughout the year, which is valuable for assessing long-term trends and compliance with the AA-EQS as specified in Annex I Part B of the EQSD[1]. This approach would calculate the annual average concentration by considering, e.g. spot or composite measurements from 12 or four months, weighted by the time interval. It captures the overall impact of the pollutant throughout the year, including the months with lower or zero concentrations. As outlined in TGD No. 19, if there are monthly measurements with two additional values in one month, the annual average is calculated by first averaging the three values within each month, then averaging the resulting twelve (or four) values. Examples suitable for such calculations include pollutants being emitted from households via waste water treatment plants throughout the year, POPs that tend to persist in the environment, and pollutants such as PAHs released in urban runoff, including from vehicle exhausts, and constant industrial emissions.

The **second approach** focuses on months when the substance is present, allowing for a more detailed analysis of seasonal trends, fluctuating concentrations, and potential sources of pollution. This detailed insight can inform targeted management actions and more effective mitigation strategies during critical periods. It is particularly valuable for operational and investigative monitoring, where higher temporal resolution than monthly sampling can enhance confidence in capturing actual concentrations, leading to a proper assessment. Shorter averaging periods are ideal for pollutants with strong seasonal patterns, where concentrations are significantly higher during certain times of the year due to specific activities or natural phenomena. Consecutive short averaging periods based on two-week composite samples can improve confidence in the assessment of substances with very episodic concentration patterns, where peaks are difficult to capture. Examples include pesticides, which reach peak concentrations following application periods typically in the growing season, and industrial chemicals due to batch production; pollutants accumulated in sediment, with elevated levels during rainy seasons or after storm events due to increased runoff and erosion, or as a result of flushing during rewetting episodes in temporary rivers; and algal toxins, which peak during warmer months when conditions favour algal blooms. Examples are given in chapter 6.1 and 6.2.

[1] Annex I Part B EQSD: For any given surface water body, applying the AA-EQS means that, for each representative monitoring point within the water body, the arithmetic mean of the concentrations measured at different times during the year does not exceed the standard.

On the other hand, more persistent and immobile substances are expected to show a potentially delayed occurrence in surface waters or a less episodic exposure pattern due to continuous leaching (run-off and drain flow). In such cases, an averaging period longer than the main emission period (maybe even the entire year) can be justified. If monthly measurements are available for the entire year, a suitable averaging period limited to the episodic peaks may also be selected based on the measurements themselves.

By understanding the nature of the pollutants and their sources, water authorities can choose the appropriate averaging method to ensure accurate assessment and thereby effective management strategies.

Regardless of whether monthly measurements or measurements over a shorter period are available for averaging, all individual measurements must be assessed against the applicable MAC-EQS. Member States may use, according to the EQSD, statistical methods, like percentile calculations, to ensure acceptable confidence and precision in determining compliance with the MAC-EQS.

6.1 Case study: Swiss concept of assessment - averaging based on Haber's rule and continuous time-proportional sampling

The numerical requirements (=EQS) set out in the Swiss Water Protection Ordinance (WPO) are derived according to the TGD No. 27 and correspond to the AA-EQS of the WFD for chronic exposure and the MAC-EQS for acute exposure. According to the WPO, the concentrations averaged over a period of two weeks must meet the chronic numerical requirements (=AA-EQS). The acute numerical requirements must be met at all times.

For assessing compliance with the numerical requirements, continuous time-proportional composite sampling is performed. To evaluate the chronic and acute requirements, samples are pooled for a period of two weeks and 3.5 days, respectively. The sampling durations and the sampling method are based on the duration of the corresponding ecotoxicity studies and on Haber's rule, as described in detail below. To ensure correct compliance assessment of a water body, samples must be taken continuously for at least four months. In catchment areas with intensive agriculture, it makes most sense to take these samples between the beginning of April and the end of November due to seasonality. Ideally, continuous sampling throughout the year is carried out and used for the assessment.

Sampling duration: Chronic ecotoxicity studies typically last between three and 28 days, with the duration varying depending on the organism under investigation: 3 days for algae, 7 days for *Ceriodaphnia dubia* and higher plants, 21 days for *Daphnia magna*, and a minimum of 28 days for fish (Figure 2a). Hence, chronic effects are expected to occur on average after an exposure time of approximately two weeks. Thus, this duration is considered an appropriate sampling duration for the evaluation of the chronic toxicity. For the evaluation of acute toxicity, based on the same considerations, a period of 3.5 days is considered appropriate.

Sampling method: In the toxicity tests performed for AA-EQS and MAC-EQS derivation, the exposure concentration is kept constant during the whole test. However, in real-world surface waters, organisms are exposed to highly fluctuating concentrations. For comparison of this fluctuating exposure in the field to the constant exposure in the toxicity tests, Haber's rule is used. Haber's rule says that the product of exposure time and concentration determines the overall observed effect, irrespective of the actual exposure pattern (Figure 2b). This means that, in theory, the average concentrations determined by time-proportional sampling should be representative of the fluctuating concentrations to which aquatic organisms are exposed. This assumption was confirmed by a scientific study using high-resolution monitoring data from Switzerland and toxicokinetic-toxicodynamic (TKTD) modelling. The study showed that time-proportional sampling for a period of 3 and 14 days for acute and chronic assessment, respectively, yields sufficiently accurate average concentrations to assess ecotoxicological effects (Ashauer et al. 2020).

Analyses of the monitoring data to date have shown that the continuous recording of chronic risks using time-proportional two-week composite samples has also revealed the majority of acute pollution episodes.

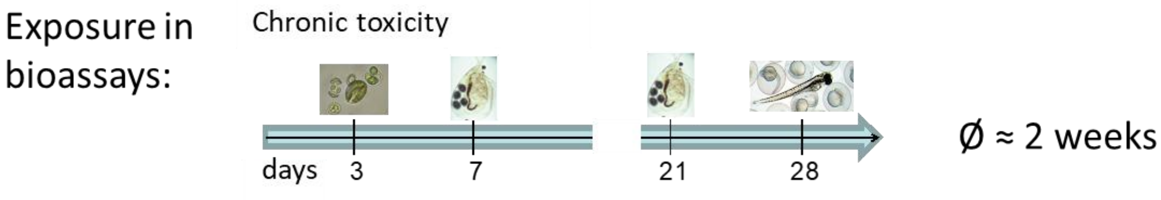

Figure 2a: Overview of the duration of the various tests used to derive chronic quality criteria. For fish, 28 days is defined as the minimum duration for a chronic test. Depending on the fish species, endpoint and test substance, longer tests may also be available. Figure adapted from Junghans et al. 2018.

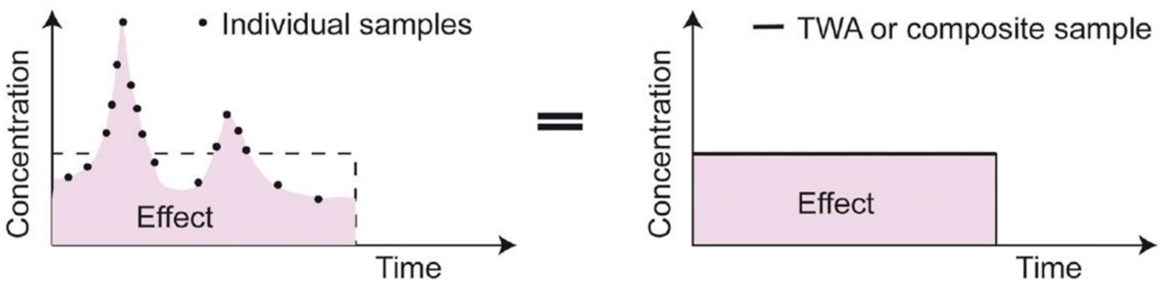

Figure 2b: Schematic illustration of Haber's rule: 'ecotoxicological effect = time x concentration'. This means that the time integral represents the same chronic effect as many individual samples (left). Figure adapted from Junghans et al. 2018.

6.2 Shorter averaging period – main occurrence of PPP exposure

The data-set obtained in the monitoring campaign for PPP in small streams, as described in chapter 5.2, covers the main application period of the PPP from April to July both in 2018 and 2019. The rain-event-based monitoring ensures that peak concentrations of PPP can be quantified and the MAC-EQS assessment gives meaningful results. Based on the measured values in these seasonal periods, the extent of EQS exceedances could be determined for the further evaluation of reduction goals. For that purpose, available measured concentrations (from grab and/or rain event triggered samples) could be averaged for comparison with the AA-EQS.

7. Integration of sampling approaches into monitoring

When applying the legal requirements of monitoring frequency as summarised in chapter 2 and implementing them as recommended in chapters 3 to 5, the selection of an appropriate sampling approach is clearly a critical factor to consider, as also implied in chapter 6.

For effective monitoring of chemical pollutants, it is recommended to combine various sampling approaches to reliably capture average concentrations, seasonal peaks, and long-term trends. Different sampling approaches may achieve different degrees of temporal resolution.

The table below summarises how various sampling approaches can be integrated into monitoring strategies for assessing average concentrations, seasonal peaks and long-term trends. Based on pollutant behaviour, temporal variability, and monitoring objectives, a tailored sampling strategy can be designed.

Table 2: **Sampling approaches and their integration into monitoring strategies**

Sampling approach	Sampled matrix	Applicable sampling frequency	Addressed monitoring purposes – Assessment of average concentrations – Evaluation of seasonal peaks – Analysis of long-term trends
Grab or spot sampling Individual samples taken at specific times	Water	Monthly, quarterly	Average concentrations, especially for continuously discharged pollutants
	Sediment, biota	Annually	Long-term trends of pollutants that tend to accumulate in sediment or biota
Composite sampling Samples collected at regular time intervals over a period, creating a time-proportional composite sample	Water	e.g. weekly, biweekly or even daily during high-risk periods	Average, peak and fluctuating concentrations, especially for sporadic and diffusely discharged pollutants
Event-driven sampling Samples collected by automated systems in response to specific conditions, e.g., after rain events	Water	Minutes to days	Average concentrations, seasonal, short-term peaks
Passive sampling Devices deployed in water for extended periods that adsorb contaminants	Water	Weeks	Long-term trends and average concentrations

Sampling methods should be selected to complement the intended analytical approach, taking into account expected environmental concentrations and the required LOQs. This includes considering whether concentrations are close to or far from the EQS, whether analytical and sampling methods can achieve sufficiently low LOQs, and the degree of temporal variability in pollutant concentrations. Taking account of these factors is essential to ensure that the data collected is representative and reliable, aligning with the specific objectives of the monitoring. Furthermore, all selected methods must comply with the requirements of Directive 2009/90/EC, although it is acknowledged that for watch-list monitoring, a standardised method may not always be available.

Grab sampling is often paired with target analysis for detecting known pollutants at expected concentrations.

Composite (sampling is well suited for target analysis as well as non-target screening as it captures broader variations in chemical pollution and provides a more representative overview of potential contaminants, including unknowns. As shown nicely by Chonova and Singer 2024, daily composite sampling for up to two weeks can capture irregular non-target profiles reliably, whereas grab sampling leads to a very large underestimation of irregularly discharged substances. A high monitoring frequency (e.g. daily) carried out by composite sampling together with a harmonised analytical method is being established along the Rhine river, which will allow an alarm-monitoring system to be put in place tracking dynamically released substances along the Rhine from Switzerland to the Netherlands using non-target screening (Rhine project non-target screening).

Passive sampling provides time-weighted-average (TWA) or equilibrium concentrations of pollutants present in water during their deployment period. Passive sampling is particularly advantageous in remote locations, or at sites that have limited security, because of its non-mechanical nature, lack of dependence on external energy sources, ease of deployment, and low maintenance requirements. Additionally, passive sampling concentrates pollutants, enhancing detection sensitivity compared to grab sampling. As recommended in the TGD No. 19 and in the EQSD, passive sampling works effectively with effect-based monitoring (EBM) and non-target screening, as it can capture bioavailable and low concentration levels, helping to detect both known and emerging pollutants (Carafa et al. 2022, de Baat et al. 2020, Miege et al. 2015, Schäfer et al. 2021).

However, passive sampling measures only the freely dissolved concentration (which is related to the biologically available fraction) and not the whole-water concentration, as required by the EQSD. As a result, passive sampling cannot be used directly to assess compliance with EQS for all organic contaminants under the WFD, but only for moderately polar to polar organic compounds (with log Kow < 5) where the concentration in the water column is not dominated by the fraction adsorbed to colloids and particles in water (Vrana et al. 2009).

Nevertheless, for hydrophobic compounds, passive sampling provides a measurement directly proportional to the chemical activity of the contaminant, which can be used to estimate partitioning onto suspended solids or biota. Since the freely dissolved concentration represents the relevant fraction driving passive uptake (bioconcentration) in aquatic organisms, passive sampling enables in-situ determination of the levels of hydrophobic bioaccumulative organic compounds that organisms *at the lowest trophic level* are exposed to. In addition, passive sampling can be integrated into a tiered approach, where passive-sampling-derived concentrations are used for initial screening by calculating equilibrium concentrations in lipids to identify areas at risk of exceeding EQS in biota, triggering biota monitoring only if exceedances are detected. More detailed information on the tiered approach can be found in Allan et al. 2025.

Currently, adsorption-based passive sampling for hydrophilic compounds allows only semi-quantitative data to be obtained due to uncertainties in applying laboratory-based sampling rates to in situ field conditions (Miege et al., 2015, Poulier et al., 2014). However, when confidence intervals for estimated TWA concentrations are available, these data could be used for EQS compliance checking.

Especially in operational and investigative monitoring, alternatives to grab sampling are particularly effective in identifying sources, pathways of pollution, and peak or fluctuating concentrations. For episodically emitted substances, grab sampling should be conducted during periods of occurrence rather than measuring these substances at equidistant intervals throughout the year (see chapter 6 on lower averaging periods). Alternative sampling approaches should preferably be applied if a reliable status assessment is not possible using grab sampling in water bodies at risk. However, if measures have already been taken to improve chemical status within a given timeline, grab sampling may be appropriate.

To detect whether a water body is being polluted by a continuous source, taking grab samples at fixed intervals is a suitable and cost-effective strategy. Passive sampling is another cost-effective method that can be applied on a larger spatial scale. However, to detect diffusely and episodically occurring pollutants, and their peak concentrations, sources and pathways, other strategies are more appropriate. Event-driven samples were chosen in a German monitoring campaign in small streams in order to detect peak concentrations of pesticides after rain events (chapter 5.2). In Switzerland, time-proportional composite samples averaging 2 weeks (taken throughout the year) and 3.5 days were selected for their suitability for comparing measured concentrations with chronic and acute quality criteria, respectively (chapter 5.1). In Sweden time-proportional weekly or two-weekly composite samples are taken to monitor the actual pesticide risks in small to medium sized catchments representing intense "worst-case" conventional agricultural management practices (chapter 5.3). In an Austrian study different sampling strategies were compared showing a systematic underestimation of annual average concentrations for substances with irregular emission patterns via grab sampling compared to composite sampling (chapter 5.4).

The following table, adapted from Spycher et al 2024, indicates monitoring strategies potentially suitable for different monitoring objectives.

Table 3: **Suitability of different monitoring strategies for different monitoring objectives** *✓✓: ideally suited; ✓: suited; (✓): limited suitability; -: not suited.* (Table adapted from Spycher et al. 2024.)

		Monitoring strategy						
		Annual biota/sediment sampling	Monthly grab samples in water	Event-driven samples in water (low to mean temporal resolution)	Time-proportional composite water samples	Flow-proportional composite water samples	Event-driven samples (high temporal resolution)	Passive sampling, where appropriate
Costs			low	medium	medium	medium	high	low
Objective of monitoring campaign	Identify water bodies polluted from continuous sources	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
	Identify water bodies polluted from diffuse sources	✓	✓	✓✓	✓✓	✓	✓✓	✓✓
	Detect peak concentrations	-	-	✓✓	-	-	✓✓	-
	Detect effect-relevant concentrations	(✓)	(✓)	✓	✓✓	(✓)	✓✓	✓
	Determine if loads decrease over time	-	-	-	(✓)	✓✓	✓	✓
	In-depth analysis of potential sources	-	-	(✓)	(✓)	✓	✓✓	✓

Since the WFD came into force in 2000, chemical monitoring has developed considerably, and knowledge on the concentration patterns of priority and other substances has substantially improved. This opens up the opportunity to design monitoring programmes that ensure a higher level of confidence in risk-based compliance assessments by increasing monitoring efforts where necessary and reducing efforts where possible.

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9. Annex

The scheme from the Netherlands presented below (translated into English) could help water managers to decide:

- whether a substance should be monitored (choice of relevant substances)
- where the substance should be monitored (location)
- when the substance should be monitored (cycle, frequency)

Use of the scheme is not obligatory; it helps to make choices. The scheme applies both to PS and RBSP, and is valid for water and biota monitoring. It does not specifically address situations where more or less frequent monitoring compared with that otherwise required by the WFD is justified.

Further details can be found here:
https://www.helpdeskwater.nl/publish/pages/162259/protocol-monitoring-en-toestandsbeoordeling-krw-errata-verwerkt-2021.pdf

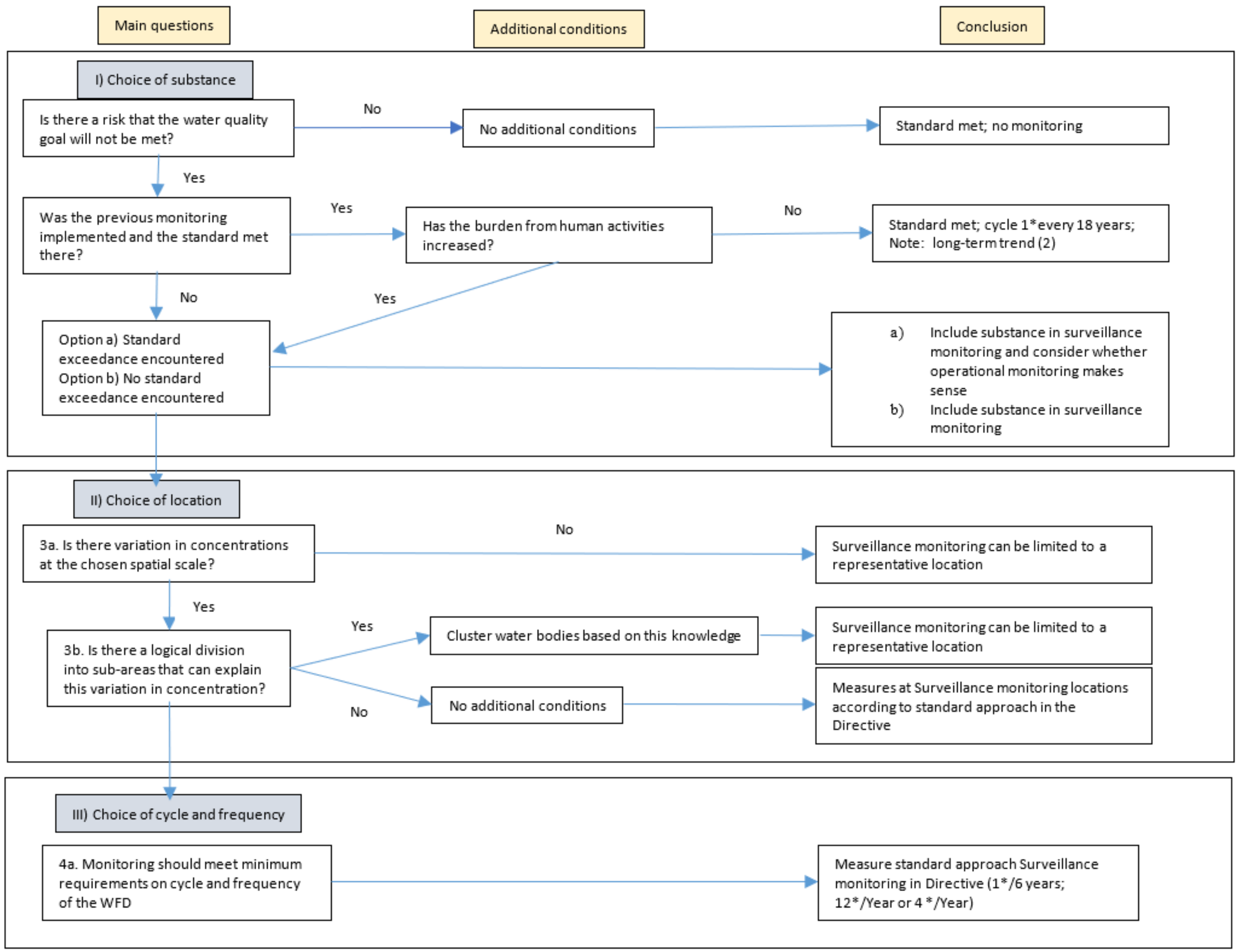

Figure 4.1 Decision diagram setting up Surveillance monitoring for priority and specific pollutants

Notes to footnotes in Figure 4.1:
1. For surveillance monitoring, good status need only be determined on a one-year basis.
If good status is then achieved and no change in emissions is anticipated, the cycle can be reduced to once every 18 years.
2. For the status assessment, the monitoring effort can conditionally be reduced. At the same time, the assessment of long-term trends requires a certain basic effort. See also sections 4.6 and 9.5.3

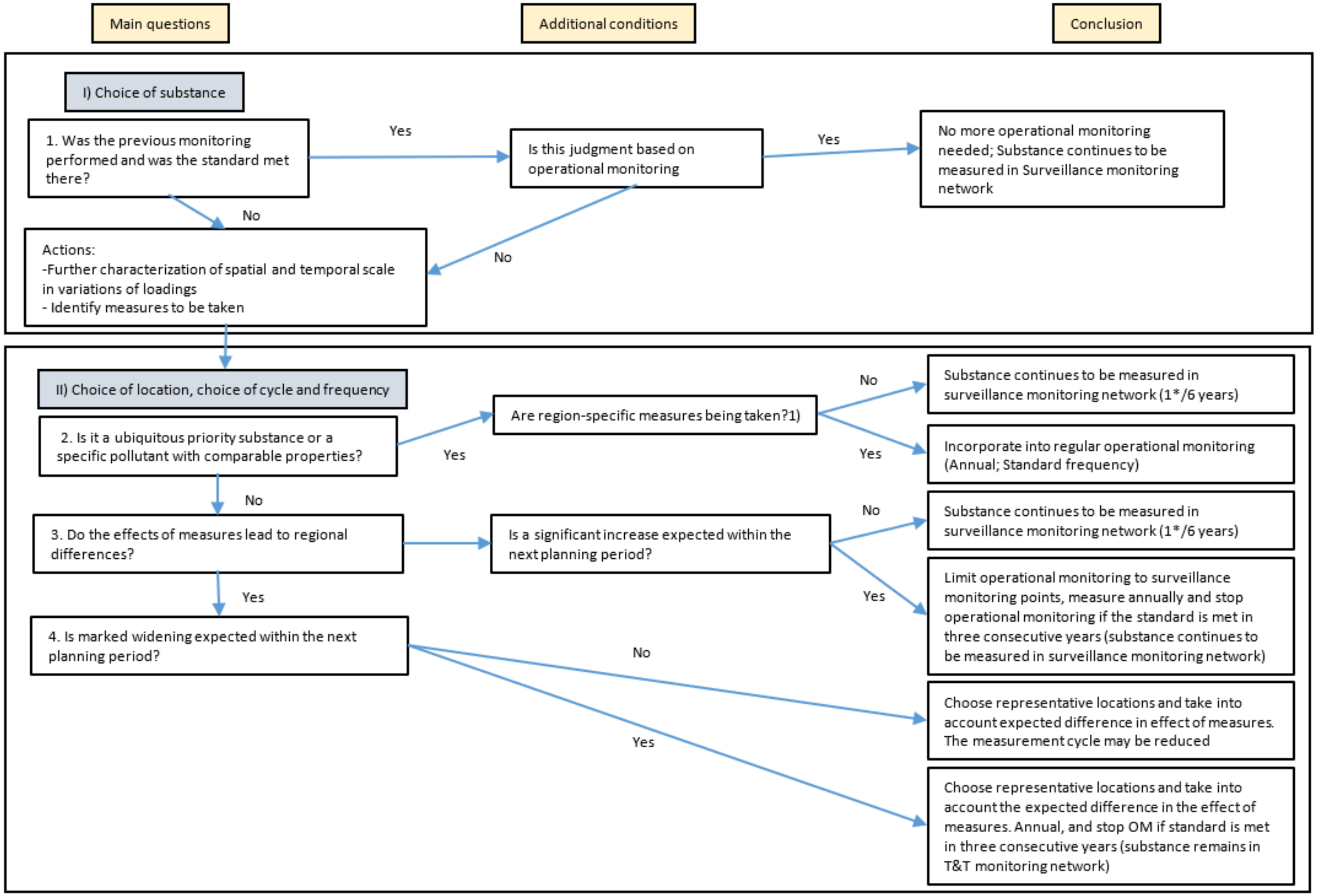

Figure 4.2 Decision diagram setting up operational monitoring for priority and specific pollutants

Explanation of footnote in Figure 4.2:

1. This question refers to recital 24 from the Priority Substances Directive. This states that "particular attention should be paid to substances that behave as ubiquitous PBTs does not exempt Member States from the obligation to take measures complementary to those already taken, including those taken at the international level, to reduce discharges emissions and losses of those substances in order to achieve the objectives of the WFD".

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